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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

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PASSENGER
ELEVATORS
AND
ESCALATORS

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Passenger Elevators and Escalators

MUCH of the basic equipment designed for and used in the modern passenger elevator and escalator has application in many different types of material handling equipment. However, the variety and scope of applications of material handling equipment cover such a wide range that it would be impossible to include all of them in one article. As a result, this discussion is limited to the lubrication requirements of the various types of equipment currently used to transport personnel in multifloor buildings, particularly offices, stores, hospitals, hotels and apartments.

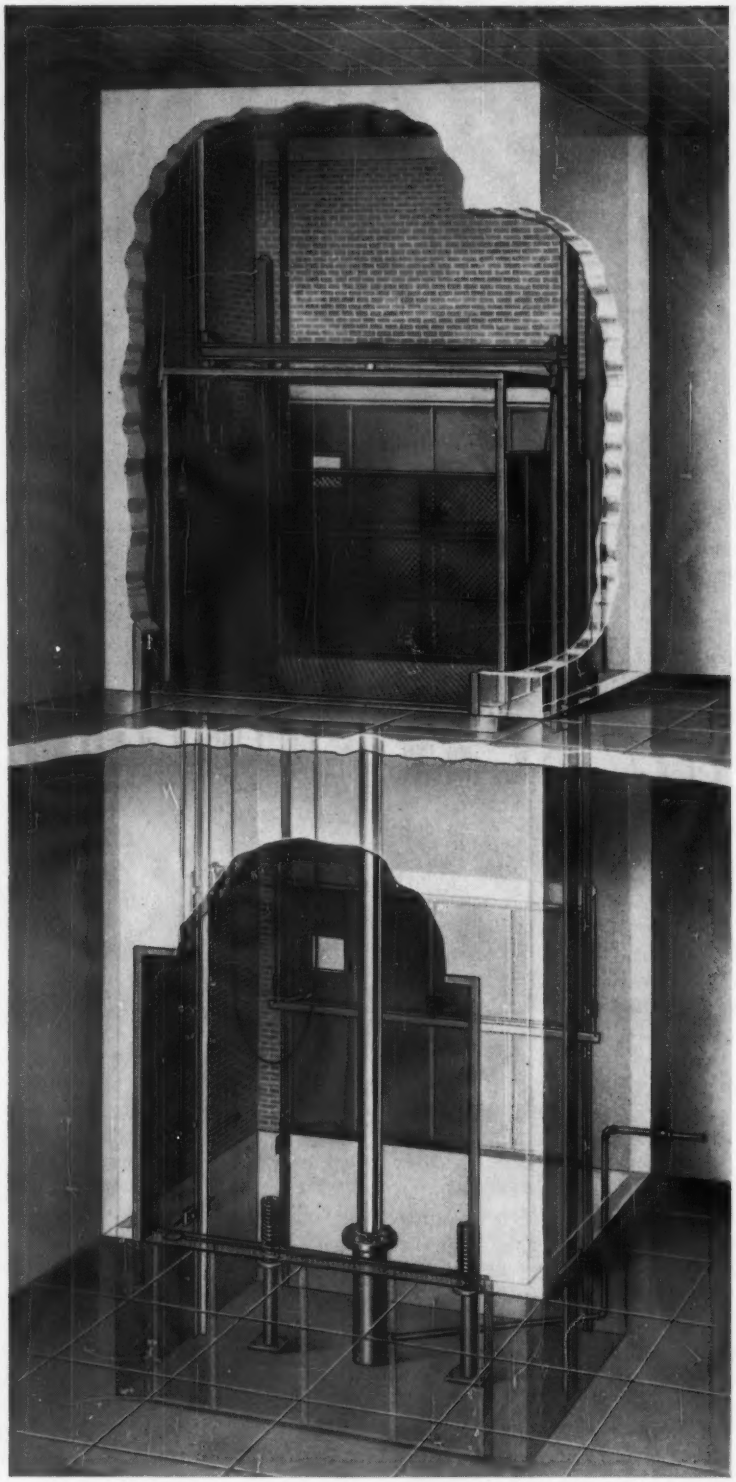
The development of safe and efficient mechanical equipment to raise and lower people for considerable distances made the skyscraper a reality. Until the first elevators and escalators were available, cities had grown upward only as far as people were willing to climb stairs.

Both the elevator and escalator have reached such common acceptance that they attract little attention. However our dependence on this means of transportation was forcibly illustrated a few years ago when the discontinuance of elevator service for a short period of time in New York City forced many firms occupying the upper floors of tall buildings to close down.

Although man or animal-powered hoists date back to Roman times, the cooperative efforts of the equipment designer, the maintenance engineer and the lubrication specialist were required to develop the modern elevator and escalator. Now twenty-five times as many passengers are carried by elevators in the United States each year as are transported by all railroads combined. Annually, more than 50 billion passengers are carried a total of 200 million miles in the 225 thousand elevators in this country alone.

Continual improvements in design accompanied with increased demands on lubricants have been necessary to meet the need for faster and more efficient vertical transportation. The early hoist, whether powered by man, water or animal power, required little lubrication. A variety of animal or vegetable oils satisfied its simple needs since the comparatively small loads and short distances traveled did not make severe demands on the lubricants. Petroleum lubricants with their increased resistance to oxidation, ability to perform satisfactorily over a wide temperature range, and greater dependability were not available for the early hoists and were not considered necessary. However, by the time elevators had developed to where they were accepted as a means of transportation and were being installed in significant numbers, the petroleum industry had also become established and was able to furnish the improved lubricants required to protect the elevator machinery when subjected to increased loads and higher speeds.

Lubricants had to be supplied that would assure safe, quiet, clean and dependable operation. When wire rope replaced hemp rope, a lubricant to protect the wire from corrosion and wear was required. With the introduction of worm gears, compounded gear lubricants were supplied.



Courtesy of Rotary Lift Company

Figure 1 — Hydraulic elevator.

Current hydraulic elevators demand hydraulic oils that protect the equipment and provide long continuous service. The increases in loads and speeds result in a demand for lubricants with greater stability. The continually wider application of the equipment also increases the severity of the demands on the lubricants. Temperatures vary over a wide range and in some cases the equipment is also exposed to wet and humid conditions. As a result, lubricants must remain fluid at low temperatures and resist the detrimental effects of water. In all of these various applications, the petroleum industry has been able to meet the challenge and provide satisfactory lubrication for the elevator industry.

HYDRAULIC ELEVATORS

The first practical elevators were developed in Europe in the 1800's and employed a direct acting hydraulic plunger working in a vertical cylinder. The elevator car or cage was fastened to the top of the plunger and the assembly raised or lowered by simply varying the pressure of water on the lower end of the plunger. In some designs, water at city main pressure was used to raise the car and wasted to the sewer as the car was lowered again. Other designs used steam-driven pumps not only to generate higher water pressures than were available from the main (thus permitting greater loads to be carried) but also to conserve and reuse the water. The water conservation feature of such a closed system permitted the next development step, namely to replace the water entirely with petroleum hydraulic oil. As a consequence the modern direct-acting hydraulic elevator like that shown in Figure 1 uses an electric motor to drive an oil pump which raises and lowers the car by "oildraulic" pressure. The nature of the hydraulic system is such that the required safety features, mostly control valves, are installed in the hydraulic power unit itself and the elaborate safety controls used on other types of elevators are not required.

However, the plunger of a direct-acting elevator must be longer than the total lift of the car, while the plunger cylinder must be sunk into the ground at least as deeply; consequently, a direct-acting hydraulic elevator is impractical for buildings of more than a few stories in height. Furthermore and while large lifting capacity is almost inherent, lifting speed is relatively low.

Maximum lift height and lift speed were both improved with the development of the hydraulic rope-geared elevator which employed higher hydraulic pressure on a short horizontal or vertical plunger carrying the movable one of a pair of sheaves. Several turns of wire rope through this and a stationary sheave greatly multiplied a small plunger movement into a large movement of the free end of the rope and the elevator car to which it was attached. While such an elevator had a much greater operating range, it also required very sensitive controls because of the multiplying effect of its cable.

In passenger service hydraulic elevators reached the height of their popularity at the change of the century and have made a most valuable contribution to building architecture. However and because of their limited operating speeds, building height restrictions and rather large space requirements, they are now largely used as heavy freight elevators in factory buildings of modest height.

ELECTRIC DRUM-WINDING ELEVATORS

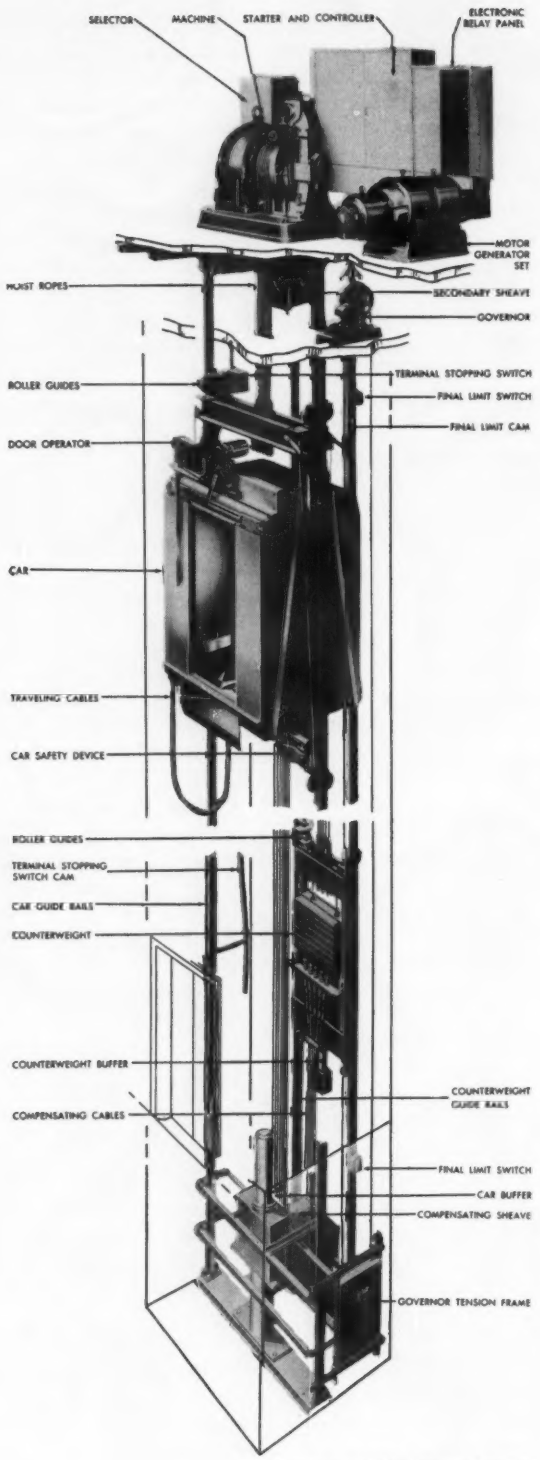
The next step in elevator development was the electric drum-winding type in which the car lifting rope was wound around a spirally grooved drum at the top of elevator shaft by means of a speed-controllable (direct-current) motor. A second rope was wound around the same drum but in the opposite direction and attached to a counterweight which approximately balanced the car weight, consequently the driving motor was required to handle only the weight of the passengers. Furthermore, in this and all modern elevators the "rope" actually consists of several smaller wire ropes in parallel which divide the load among them and thus provide better rope flexibility, life and dependability.

One of the first elevators in America of the drum-winding type was installed in 1889 by the Otis Elevator Company in New York City's Demarest building. A direct-current motor was used to drive the drum through a worm type reduction gear. Possibly in this early one but certainly in later machines, the worm gear was of the reversible or non-locking type; consequently, the motor on a descending car could generate and return electrical energy to the supply lines.

Since all the rope had to be wound upon the drum, the size of the latter increased with building height, consequently such an elevator was usually restricted to a building of not more than 150 feet (about fifteen stories) in height. Car speeds were also limited to approximately 350 feet per minute by the somewhat rough starting and stopping that the simple rheostat-controlled direct-current motor of that day provided.

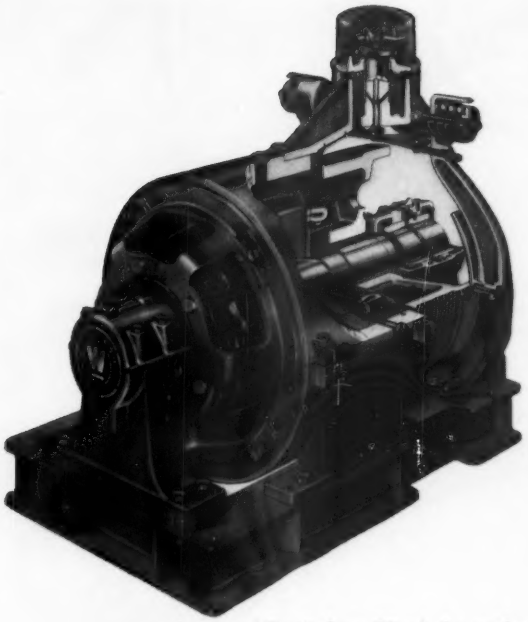
ELECTRIC TRACTION ELEVATOR

To overcome the limitations of the drum-winding machine by providing greater elevator travel and higher lift speeds, the modern electric traction elevator illustrated in Figure 2 was developed. In this machine the cables from the car are not wound around a drum but instead are passed over the motor driven upper sheave and thence down to the



Courtesy of Otis Elevator Company

Figure 2 — Details of high speed completely automatic passenger elevator.



Courtesy of Westinghouse Electric Corporation

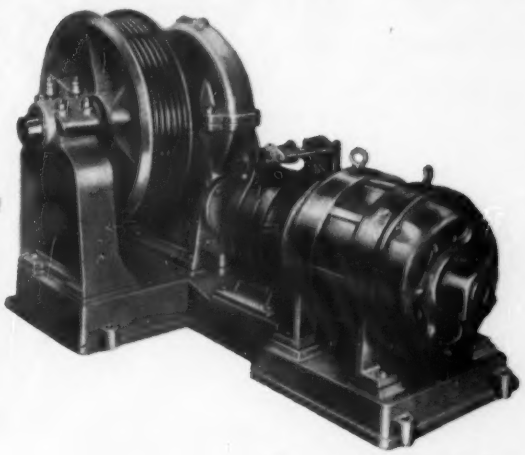
Figure 3 — Gearless traction machine.

counterweight. Furthermore a second set of cables connect the bottom of the counterweight to the bottom of the car through a compensating sheave. Thus the car is actually a link in a continuous rope system and is driven by friction between the upper sheave and the rope. The compensating cables not only eliminate the surge or "whiplash" effect of a single cable on upward deceleration, but adjust and maintain constant friction between the ropes and drive sheave, the whole providing the remarkable smoothness and sense of certainty provided by the modern elevator. The high speed of the modern traction elevator (up to 1400 feet per minute), its wide operating range, its smoothness of operation and its adaptability to automatic operation all recommend it for use in the modern skyscraper.

At the option of the designer, the upper sheave may be driven either directly by the motor as shown in Figures 2 and 3, or may be powered through a reduction gear as illustrated in Figure 4. In all three examples the reader's attention is also invited to the electric solenoid-operated brakes which are mainly used to lock the car at floor level during loading and unloading.

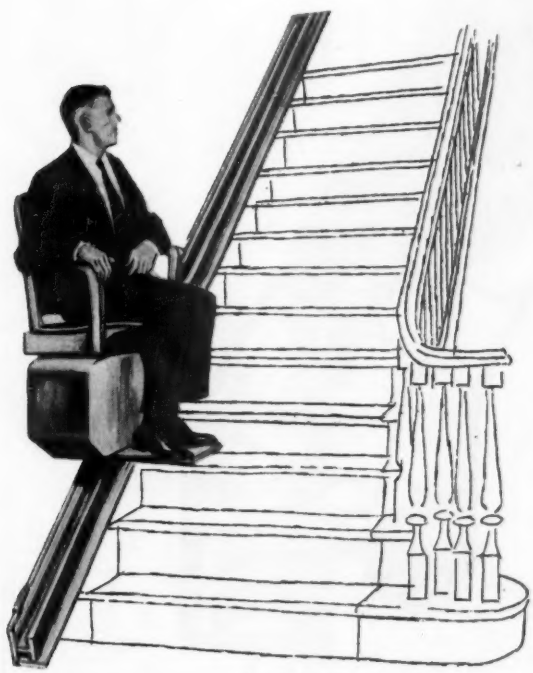
INVALID LIFT

Figure 5 illustrates a "stairway" or "invalid" lift which is a special form of private elevator operating on an inclined rail to one side of a stairway. It can be readily installed in most multi-floor private houses and has proven to be a boon to cardiac and other physically handicapped individuals.



Courtesy of F. S. Payne Company

Figure 4 — Geared traction machine.

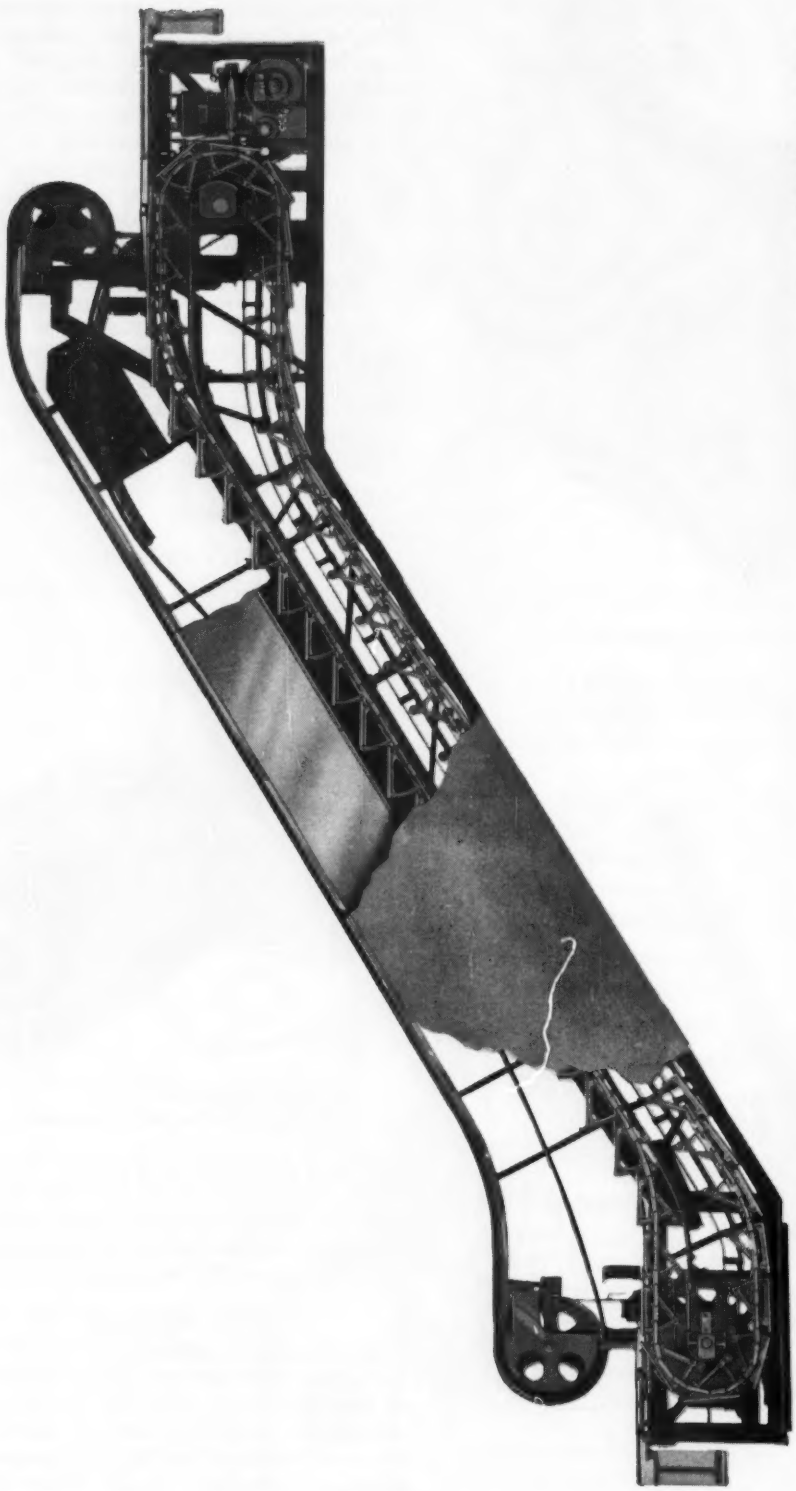


Courtesy of Sedgwick Machine Works

Figure 5 — Invalid lift.

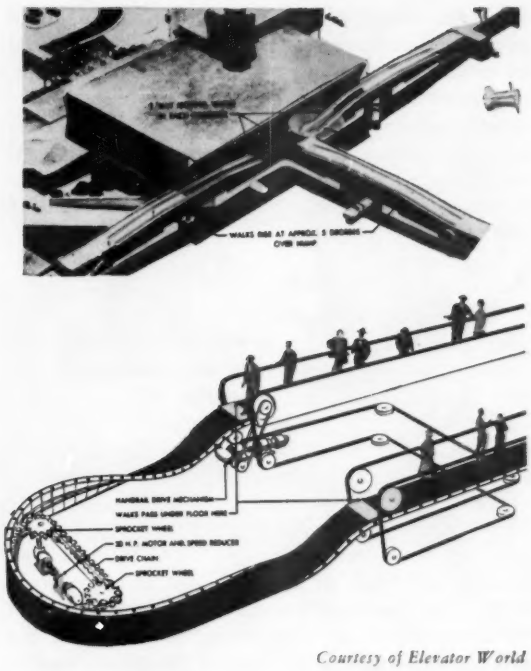
THE ESCALATOR

Any elevator is essentially an intermittent device in the sense that it accepts and transports one group of passengers at a time. On the other hand the escalator or "travelling stairway" shown in Figure 6 is a continuous device that can transport a steady stream of passengers. In fact within its range an escalator can frequently transport more passengers



Courtesy of Otis Elevator Company

Figure 6 – View of modern escalator.



Courtesy of Elevator World

Figure 7 — Passenger conveyors installed at Dallas airport.

than two or more elevators. It is actually a type of conveyor consisting of a series of folding steps attached to endless chains guided in a steel truss and driven steadily through sprockets by a geared electric motor. Handrails moving at the same speed as the stairs are always provided.

THE MOVING SIDEWALK

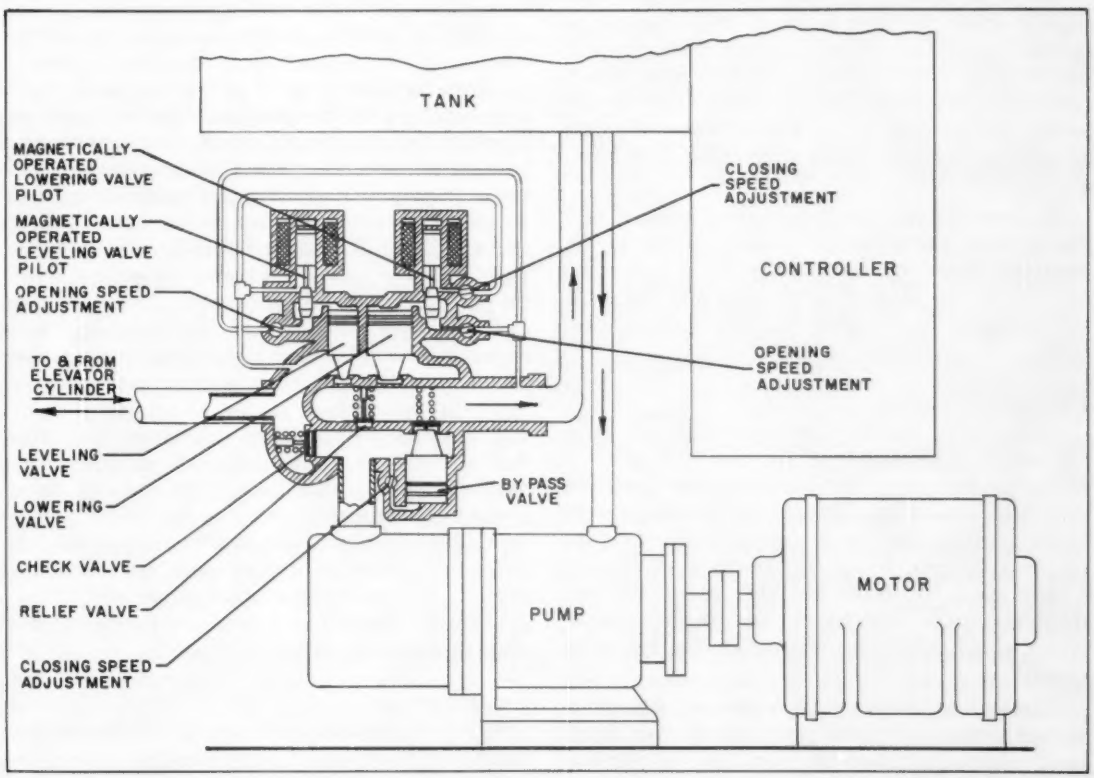
Figure 7 presents a "moving sidewalk," an interesting extension of the escalator principle. The lower portion of the figure illustrates the method used for turning the wide sidewalk belt, thus enabling its additional useage in the opposite direction.

CONTROLS FOR POWER UNITS

To keep pace with the demands for higher speeds, and the need for smoother acceleration and retardation, elevator controls of necessity have undergone considerable development.

Hydraulic Elevators

The early hydraulic unit controls consisted of little more than a simple system to start and stop the flow of the hydraulic fluid. In some the control and lift rope was simply attached to a counter-



Courtesy of Otis Elevator Company

Figure 8 — Drawing of valve arrangement in hydraulic lift power unit.

weight bucket that traveled in a standpipe as high as the elevator shaft. By adding or discharging water, the bucket was made heavier or lighter than the car, causing the latter to ascend or descend. The water was taken from a tank at the top of the shaft and the discharge from the bucket dropped down the standpipe into a reservoir in the basement from which it is pumped back up so it could be used over and over.

As indicated in Figure 8, today's hydraulic passenger elevators employ a far more sophisticated electrical control system. A triple screw pump driven by an electric motor is used to obtain quiet operation and a smooth non-pulsating flow. The pump discharges through a check valve which oil-locks the elevator car in position. A pressure relief valve is also used, and in the case of excessive pressure the oil by-passes into the oil return line and the tank. In addition to a down valve that drains the hydraulic cylinder, an accelerating valve and a leveling valve are used for smoother starting and stopping.

On starting the car, the accelerating valve by-passes part of the pump output into the reservoir and as this valve closes the car is accelerated. When fully closed, all of the pump discharge goes into the hydraulic cylinder and the car runs at rated speed.

When the pump is stopped, the car comes to rest slightly above the floor to which it is signaled. A car cam then closes the leveling switch which opens the leveling valve, permitting oil to flow slowly from the jack cylinder. This flow from the cylinder brings the car back to floor level where the cam releases the leveling switch which closes the leveling valve.

To lower the car, the down valve is actuated and the oil from the hydraulic cylinder returns to the reservoir. However, this valve is closed before the car reaches the desired floor level and the final adjustment is again made with the leveling controls.

Electric Elevators

Early electric models were controlled by a rheostat which accelerated or retarded the elevator motor by increasing or decreasing the armature and field resistance. Changes in direction were easily accomplished by a switch which reversed the lead connections to the armature. Resistance control characteristically had high power loss and relatively rough acceleration. The rheostat control system also limited the elevators to relatively slow speeds.

These disadvantages were overcome by a multi-voltage control. A motor-generator set was developed which controlled the speed of the elevator by varying the field of the d-c generator which in turn varied the voltage impressed on the d-c motor. Since the motor of the motor-generator set used alternating current, this system no longer required an external source of direct current which is becoming increasingly scarce. Figure 2 illustrates such a motor-generator set together with the various electric and mechanical controls. Most modern elevators, gearless or geared, which operate at speeds greater than 100 feet per minute, use the variable voltage system.

Auxiliary Equipment

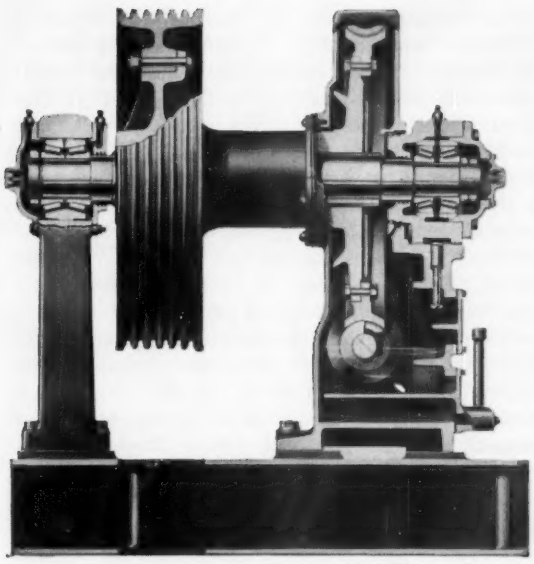
While not readily evident to the casual passenger, many safety devices as well as many additional auxiliary pieces of equipment are provided to protect the passenger and give the efficient service expected from the modern elevator. All elevators, of necessity, incorporate many safety devices. In the hydraulic systems, many of the safety features like check valves, by-pass valves and relief valves, are built into the control unit. Limit switches to prevent the car or counterweight from being pulled into the overhead structure are not necessary since even if the operator ran the elevator to the limit of the up-travel, the plunger bottom would hit the cylinder head and stop. Then if the pump continued to run, the excess pressure would merely open the relief valve and by-pass the oil back to the storage tank with no resulting damage. On lowering, the car can only go down until it rests on the bumpers or the plunger hits the cylinder bottom. In either case, the speed is so low that no harm is done and for these reasons the control of hydraulic elevators may be stripped to the barest essentials.

However, the faster electric traction-driven elevators require limit switches and many other safety devices. Governors are used to safeguard against over-speeding. If a car begins to speed beyond its limit, the governor cuts off the power and motivates the machine brake. Safety brakes that clamp the guide rails are also provided. The automatic door operators are provided with electronic detectors that protect the passenger when entering or leaving the car.

Electronically controlled elevators like that shown in Figure 2 automatically coordinate their own operation by distributing service to all floors as the traffic demands. Cars that are loaded quickly are dispatched ahead of schedule and by-pass calls from other floors until their loads are sufficiently reduced to accommodate more passengers. These operator-less systems have improved the service and reduced operating expenses.

Escalators

While the escalator was introduced after the elevator and its applications are somewhat more limited, it too underwent considerable development resulting in the modern type illustrated in Figure



Courtesy of Otis Elevator Company

Figure 9 — Sheave of a geared traction machine.

6. The travelling stairway of today is powered by an electric motor. Through a series of reduction gears, the motor drives the sprocket assemblies which in turn motivate the hand rails and the continuous stairway. Like elevators, safe, rapid and efficient transportation are of primary concern. Consequently emergency braking equipment and governors to provide speed control, are also employed. Step design in regard to width, speed, and stability make it easy for everyone to get on or off the modern escalator.

LUBRICATION PROCEDURES

The main types of equipment discussed in this article are made from a wide variety of components that might seem to require many different types and grades of lubricants to keep them functioning properly. However many of the components are similar in nature with regard to their lubricating needs. As a result, the lubrication problems of the individual components will be discussed. In some cases of course a component will only be applicable to one type of unit; for example, the problem of lubricating step chains is only encountered in escalators.

Power Units

All of the present day equipment is powered by electric motors. Some of the larger elevator installations employ motor generator sets to facilitate control. However, the type of bearings used in these motors governs the selection of the proper lubricant. The ball and roller bearings are usually lubricated with a ball and roller bearing or a multipurpose type grease that has been inhibited to prevent oxidation, rust and corrosion, and has good water resistance characteristics. The grade used is largely dependent upon the temperature range the bearing will encounter. If the initial starting temperature is low, a product that keeps the starting torque to a minimum is advantageous.

Grease lubrication of ball and roller bearings has certain inherent advantages. The bearing design can be simplified since oil tight seals are not required. With the reduction of leakage the machinery may operate under normal conditions for longer periods of time without relubrication. The correct type of grease also forms an effective protective coating at the bearing edges, which seals the bearing against dirt and moisture.

When relubricating ball and roller bearings, caution should be used not to "over-pack" the bearings. An excess of grease will lead to the development of abnormal bearing friction and overheating, which could cause leakage. This is extremely objectionable in electric motors due to the possibility of the lubricant fouling the commutators and windings.

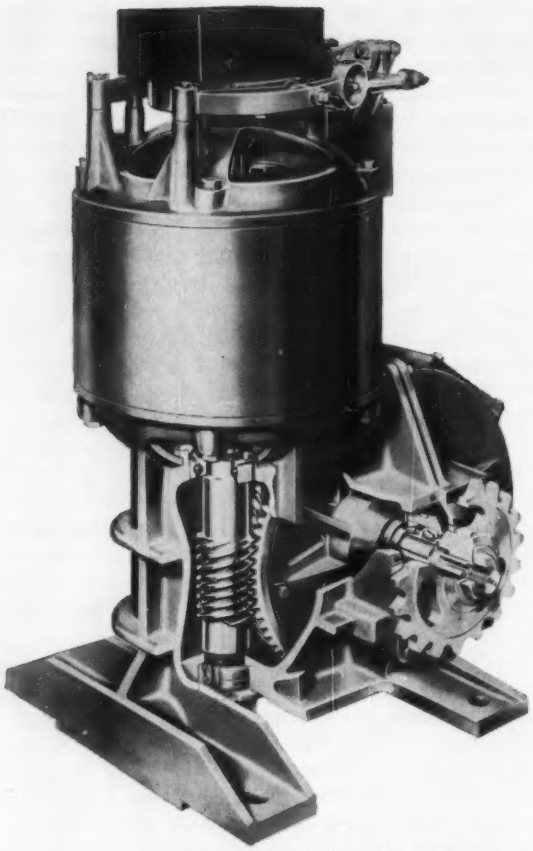
When motors have plain bearings with chain or ring oilers, a rust and oxidation inhibited oil having a viscosity in the range of 200 to 300 Saybolt Universal Seconds at 100°F is usually used. Lubrication of these bearings is not considered particularly difficult and the only problem usually encountered is maintaining the proper oil level. Regular maintenance schedules provide for the addition of oil when necessary, and inspection of the chain or ring oilers to insure that they rotate freely with their shafts.

Sheave Bearings

As in plain motor bearings, a rust and oxidation inhibited oil is used to lubricate sheave bearings like that shown in Figure 9. However, sheave loads are considerably higher with the result that a more viscous oil such as one with a viscosity of 1900 SUS seconds at 100°F is frequently used. Again the only problem encountered is maintaining the proper oil level.

Worm and Reduction Gears

Worm and spur or spiral reduction gears are encountered in the geared traction elevator power units and escalator machines. Since the worm gears in the traction units are subjected to repeated high loads during starting and stopping operations, a mild extreme pressure lead soap type of gear lubricant which is noncorrosive to the gear metals is considered advantageous. While the viscosity of a worm gear lubricant is dependent upon gear size, operating speed and temperature, a viscosity in the range of 125 to 150 SUS seconds at 210°F is



Courtesy of Westinghouse Electric Corporation

Figure 10 — Escalator machine and worm gear.

widely used in this application. Figure 10 illustrates the worm type reduction gear used in a popular escalator.

A satisfactory mild extreme pressure lubricant should (1) exhibit no additive separation, (2) have maximum resistance to foaming, (3) be noncorrosive to the metals encountered even in the presence of water, and (4) be resistant to oxidation. Closed gear sets of spur or spiral type require a product similar in nature though a different viscosity may be recommended.

For open gears an extremely adhesive viscous product applied at regular intervals is required. The manufacturer can best recommend the frequency and method of application. Figure 11 illustrates an open helical gear type of reduction gear which would require such a lubricant.

Guide Rails

Many of the guide rails on today's elevators do not require lubrication since rollers rather than sliding shoes are employed. However, where sliding type shoes are still in service, guide rail lubrication remains a problem. Since the safety jaws grip the rails to stop the car in the event of mechanical failure, many lubricants that would otherwise be satisfactory for lubricating sliding applications cannot be used. The safety of the elevator depends upon the jaws of the safety clamp being able to break through the oil film and apply a constant retarding force to the guide rails. This unusual requirement prohibits any lubricants with extreme pressure characteristics. The American Standard Safety Code for Elevators also advises against excessive amounts of *any* type of lubricant on rails and prohibits the use of paint or any material that will adversely affect the action of the safety jaws. An uninhibited mineral oil with a viscosity of about 300 SUS at 100°F applied at regular intervals has been found satisfactory. In other applications, a semifluid grease is applied sparingly. In some instances, the distance traveled by the elevator determines the frequency of application.

Wire Ropes and Cables

Since the movement of the elevator car in both the geared and gearless traction systems is dependent upon the friction developed between the cable and the sheave, the selection of the proper lubricant for wire cables is probably one of the most perplexing lubrication problems in the elevator industry. While it is generally agreed that some type of wire rope lubricant should be used, there is very little uniformity in the types of products recommended or in the methods of applica-

Courtesy of Otis Elevator Company

Figure 11 — Escalator machine and reduction gears.

tion. Regardless of whether the product selected is a heavy viscous material or a low viscosity product containing a volatile fraction, it must protect the wire rope from rust, corrosion, abrasion and lubricate the strands when the rope is stressed and squeezed by the action of the load and the movement of the sheave. Methods of application are just as controversial. Some materials are applied by brushing, others are applied with a roller similar to the type used to apply paint. Some units have special wire rope oiling equipment. However, there seems to be no universally accepted answer to the problem and each installation requires special consideration of the operating conditions encountered.

It is generally agreed that a lubricant for wire rope should have the following characteristics:

1. It should not harden nor contain any solid matter that is of nonlubricating character.

2. It should have a high penetrative property in order that it can work its way between strand wires to lubricate them and the interior of the rope.

3. It should be water resistant and prevent other destructive material from coming in contact with the strands.

4. It should be adhesive to resist dripping or throwing off as when passing around a sheave.

Any wire rope lubricant should be applied sparingly since excessive amounts will (1) reduce the coefficient of friction between the rope and the sheave, (2) run off the rope and down into the elevator car, (3) collect a variety of foreign dirt and abrasive material on the rope.

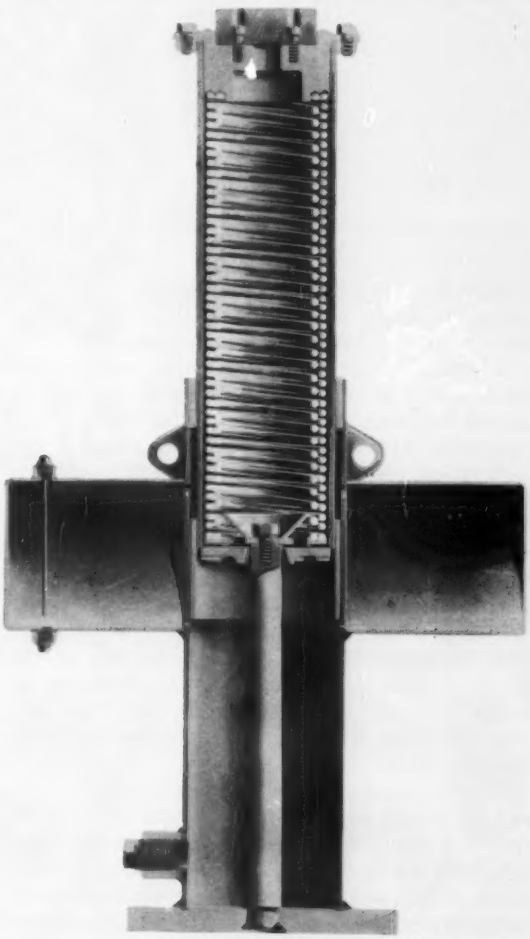
Miscellaneous Equipment

All four systems, the hydraulic, the geared and gearless units and the escalator, use a large variety of miscellaneous equipment that requires maintenance and lubrication to assure the proper functioning of the units. As examples, the automatic hoistway doors are supported on rollers and operated by small electric motors. Many guide shoes employ rollers, the governors that prevent overspeeding, the braking mechanisms on the power units and the safety interlocks are all essential to the safe and efficient operation of the major units. Their lubrication requirements, however, have been pretty well standardized and in most cases a multipurpose grease or a medium viscosity rust and oxidation inhibited oil will provide adequate protection and insure continued satisfactory operation.

Buffers

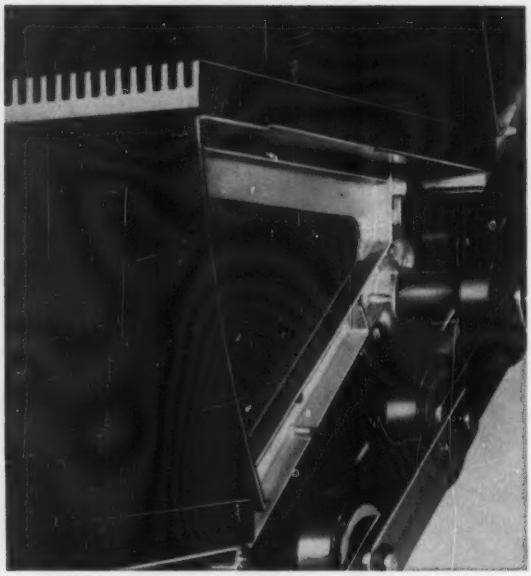
All elevators use spring or oil type buffers which are located in the pit and are designed to bring the car or counterweight to a smooth stop if either attempts to overtravel their lower landing limits during normal operations. Buffers are not designed to stop a falling car. Other safety features will stop a falling car before it reaches the buffers. In the case of oil buffers as shown in Figure 12, the pressure from the descending car forces the oil through escape holes and produces sufficient resistance to retard the car motion. The spring returns the plunger to the normal position when the car is lifted and the oil returns to the inner cylinder.

The viscosity of oil selected for this type of service is dependent upon the size of the escape holes and the rated capacity of the buffer. However, the American Standard Safety Code for Elevators does specify the general requirements that oils shall have a pour point of 0°F or lower and a minimum viscosity index of 75. This information along with the rated minimum and maximum loads shall also be clearly indicated on the name plate. Since the buffers are located at the bottom of the elevator shaft where exposure to humid conditions could frequently occur and their reliable operation depends upon an oil whose viscosity will remain



Courtesy of Westinghouse Electric Corporation

Figure 12 – Oil buffer.



Courtesy of Otis Elevator Company

Figure 13 — Escalator step chain with rubber-faced rollers to reduce noise.

relatively constant, a rust and oxidation inhibited oil should be used to assure stability and prevent an accumulation of rust and sludge.

Hydraulic Systems

The selection of a suitable oil for an hydraulic elevator like that shown in Figure 1, is the most important single lubrication factor in this type of unit. Since the hydraulic medium not only raises and lowers the car but also lubricates and protects the majority of associated equipment, use of the correct hydraulic oil is the best guarantee of long equipment life and reliability. It is essential that such an oil contain rust and oxidation inhibitors: when exposed to humid conditions, the plunger must be protected to prevent rusting or corrosion since any rough spots on the plunger caused by rust will result in excessive packing gland wear. Consequent leakage through the packing gland and loss of pressure would make maintaining the car level an impossibility. Oxidation stability of the oil is of equal importance: any accumulation of sludge from oil oxidation products would not only plug filters but interfere with the operation of the control valves.

Since it is impossible to keep atmospheric water and air out of hydraulic systems, the oil must be emulsion and foam resistant. Any moisture that enters the system through contamination or condensation should separate easily from the oil. An emulsion of water and oil could promote the collection of dirt, adversely affect the proper functioning and have a detrimental effect on the oil's foam resistance. Air can enter the hydraulic system at many places: certain types of pumps may introduce air through their seals. As in the case of water, the air and oil should separate easily and quickly. If relatively large quantities of air remain in the oil, foaming will result when the oil pressure is decreased and cause car leveling difficulties. A highly refined premium hydraulic oil inhibited against rust and oxidation is an absolute necessity for hydraulic elevators.

Escalators

Maintenance of the step chain, as illustrated in Figure 13, is the most critical lubrication problem encountered in escalators. While such maintenance practices as proper adjustment of the chain tension help to prolong the chain life, the chains are exposed to a wide variety of operating conditions and make severe demands on the lubricant. Since some rollers (like those in Figure 13) are rubber-surfaced, no leakage of lubricant from their bearings should be permitted. Either a ball and roller bearing or a multipurpose grease having good rust prevention, oxidation stability and low starting torque characteristics is generally recommended.

General Considerations

While neatness and cleanliness are always good maintenance practices, they are of particular importance to the elevator and escalator industry. These conveyances are called upon to transport large numbers of people every day and give visitors their first impression — good or bad — of the building being visited. Poor or improperly applied lubricants may not only soil passengers' clothing, but become a fire hazard in an elevator shaft. Clean, oil-free shafts not only reduce fire hazard but also prolong the life of the equipment itself by reducing wear from dirt accumulated by the presence of excessive amounts of lubricants.

In all installations keeping the noise level to a minimum is a serious consideration for the industry. Where possible, units are mounted on rubber, and rigid frames are employed to reduce vibration noise. The selection of the proper lubricants, properly applied at regular intervals are major aids in keeping noise at minimum levels.

SUMMARY

As a result of their general acceptance, elevators and escalators are required to operate under a wide range of conditions and their successful operation is partly due to the petroleum industry's ability to meet the increasing demands for better lubricants. In the future the public can expect faster, safer and more efficient vertical transportation which will require premium petroleum products to protect and guarantee its smooth operation.

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